Marginal Sea – Open Ocean Exchange

Michael A. Spall
Department of Physical Oceanography, MS #21
Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1541
phone: (508) 289-3342 fax: (508) 457-2181 email: mspall@cms.whoi.edu

Award Number: N00014-01-1-0165

LONG-TERM GOALS

The long-term goal of this project is to contribute to our understanding of the circulation, exchange, and environment between marginal seas and the open ocean.

OBJECTIVES

The objective of this study is to better understand how the exchange between a marginal sea and the open ocean and the circulation within the marginal sea depends on the wind- and buoyancy-forcing in the marginal sea and open ocean. Areas of focus include: mass and heat flux through the straits; circulation pathways in the marginal sea; regions of large air-sea heat flux; regions of deep mixing and downwelling in the marginal sea.

APPROACH

The approach is to develop analytic and numerical models that demonstrate how the exchange between the marginal sea and the open ocean, and the circulation within the marginal sea, depend on buoyancy- and wind-forcing. The models are applied to the circulations in the Japan / East Sea and the Indonesian throughflow. The basin configurations are necessarily idealized in order to permit simple representa-tions of the important geometrical and physical parameters, and to determine their influences on the quantities of interest. The overall objective is to provide simple physical explanations for the dominant aspects of the observed circulations in the marginal seas. Numerical models will also be applied to realistic configurations to test the theoretical results in a more complete context.

WORK COMPLETED

Models have been developed for two regions: the Indonesian throughflow and the Japan / East Sea (JES). In each case, analytic and numerical models have been developed for idealized configurations representative of these two regions. Integral constraints have also been developed that relate the net circulation around the island, and its baroclinic structure, to the atmospheric forcing and the island configuration. For the case of the Indonesian throughflow, the analytic model shows that the upper ocean zonal current in the eastern Indian Ocean impinges on the west coast of Australia and forms the poleward flowing Leeuwin Current. Circulation integrals around the island were used to infer the influences of this eastern boundary current on the baroclinic exchange between the Indian and Pacific Oceans. Comparisons have been made between the analytic predictions and results found in a two-layer primitive equation model for both idealized and realistic configurations.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Marginal Sea - Open Ocean Exchange**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Physical Oceanography, MS #21,,Woods Hole Oceanographic Institution,,Woods Hole,,MA, 02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal of this project is to contribute to our understanding of the circulation, exchange, and environment between marginal seas and the open ocean.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Different analytic and numerical models of the JES have been developed to determine the influence of buoyancy loss in the JES on the circulation within the JES and the exchange with the Pacific Ocean. Estimates of the exchange rate and regions of downwelling have been derived from the analytic model and compared with the numerical model.

RESULTS

The common result between these two studies is the finding that buoyancy-forcing within a marginal sea modifies the circulation within the marginal sea and the baroclinic exchange between the marginal sea and the open ocean. The exchange is most strongly influenced if the heat loss takes place along the west coast of the island, as found near western Australia and western Japan. There is generally close agreement between the analytic and numerical models, lending confidence to the basic parameter dependencies that the analytic models provide. Key parameters are the ratio of the diffusive and thermal boundary layer widths and the relative change in the Coriolis parameter between the two straits that connect the marginal sea to the open ocean.

For the case of the Indonesian throughflow, realistic models indicate that an upper ocean buoyancy-forced circulation of $2–3 \times 10^6$ m^3/s flows from the Indian into the Pacific Ocean (Figure 1), in opposite sense to the $5–10 \times 10^6$ m^3/s of wind-driven transport. This circulation is forced by heat loss in the Leeuwin Current, an eastern boundary current along the west coast of Australia. These results provide a simple explanation for the observed subsurface maximum in the strength of the throughflow.

The models also show that cooling with the JES forces a branching of the wind-driven inflow transport in the southern JES into eastern and western boundary currents, in qualitative agreement with the observed circulation. The eastern boundary current is a region of intense heat loss to the atmosphere and downwelling. The upper ocean transport through the Tsushima and Tsugaru Straits has been found to be strongly dependent on this cooling, as well as on the heat flux along the east coast of Japan in the Pacific Ocean.

IMPACT/APPLICATIONS

These results demonstrate how the exchange between marginal seas and the open ocean depends strongly on the physical processes with the marginal sea. This not only points to the importance of buoyancy-forcing and a proper representation of eastern boundary currents for basin-scale models, but also suggests that care must be taken in the specification of the strait transports for regional models of marginal seas. The regions of strong air-sea exchange predicted by these models are also regions of strong upper ocean temperature gradients and are important regions for biological productivity.

TRANSITIONS

The physical understanding provided by these simple models focuses attention on the key processes that must be properly represented in predictive models of these regions. This should allow for better predictions of the ocean currents and their sensitivity to air–sea exchange in such marginal seas.

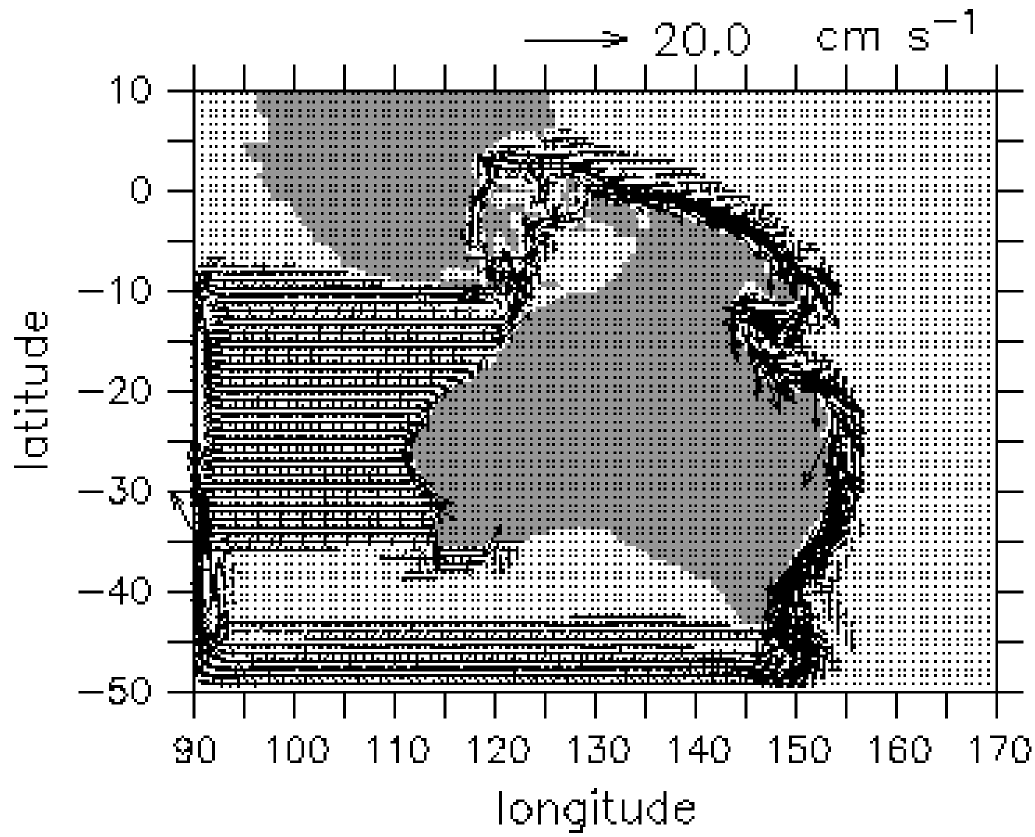

Figure 1: Upper ocean circulation in the vicinity of Australia and the Indonesian throughflow forced by an eastward flowing current in the eastern Indian Ocean. Approximately 7.6 $\times 10^6$ m^3/s flow eastward towards the west coast of Australia, of this amount 2.6 $\times 10^6$ m^3/s (34 %) flows through the Indonesian throughflow from the Indian Ocean into the Pacific Ocean. This transport circulates cyclonically around Australia and returns to the Indian Ocean around the southern tip of Australia. This circulation is in close agreement with the theory, which predicts a cyclonic circulation strength of 2.8 $\times 10^6$ m^3/s (37 %).

RELATED PROJECTS

This study is closely related to the ONR-funded Japan / East Sea program (JES) and the ONR LINKS Dynamical Linkage of the Asian Marginal Seas) program, which use a combined observational and modeling approach to study the circulation and exchange between the Asian marginal seas and the open ocean. The ONR ASIAEX (Asia Seas International Acoustics Experiment) volume interactions program in the South China Sea also addresses some common issues of marginal sea/open ocean exchange, as does the Circulation Research on the East Asian Marginal Seas (CREAMS) program being jointly supported by Korea, Japan, and Russia.

PUBLICATIONS

Spall, M. A., 2001. On the baroclinic structure of the Indonesian throughflow. *Journal of Physical Oceanography*, submitted.

Spall, M. A., 2001. Wind- and buoyancy-forced upper ocean circulation in two-strait marginal seas with application to the Japan / East Sea. *Journal of Geophysical Research – Oceans*, submitted.

Spall, M. A., 2001. Numerical Modeling: The Forward Problem. Chapter in: *Encyclopedia of Ocean Sciences*, in press.